Global Climate Change and Its economic impact on Sub-Saharan Africa: *Simulation of a Computable General Equilibrium Model for Ethiopia*

Endeshaw Wolde, Tebelo

Master Thesis

Department Of Economics

Faculty of Social Science

June 2008

University of Oslo

Acknowledgements

I would like to express my gratitude to all those who gave me the possibility to complete this thesis. I am deeply indebted to my supervisor Asbjorn Aaheim from Center for International Climate and Environmental Research-Oslo(CICIRO) whose insightful remarks, stimulating suggestions and encouragement helped me in all the time of research for and writing of this thesis.

I owe a debt of gratitude to my dear friend Torben Kenea for his helpful advices and supportive guidance in the procedure of doing this thesis.

Endeshaw Wolde, Tebelo

June, 2008

CONTENTS

List of Tables

Abstract

An Increase in temperature and reduction in precipitation beyond the ideal threshold undermines agricultural productivity which is likely to be worse in the tropics due to vulnerability of the agricultural systems to climate change and low adaptive capacity in the region. In line with this an attempt is made to show the wake up call from the sleepless changing world climatic condition by analyzing its Economic impact in Ethiopia, one of the poorest economy in Sub-Saharan Africa . Using the CGE model the backward and forward linkage between sectors and the specific impacts on producers, consumers and other institutions are analyzed. The results show that climate change through its impact on the major sector agriculture has a significant negating effect on consumption and production in the rest of the economy. The study result also suggests that unless immediate action is taken to combat global warming and hence climate change, sub-Saharan Africa and the entire community of already poor and vulnerable people in the nation may face the worst in the years to come.

I. Introduction

Background

Inherent in human activity, climate is a dynamic phenomenon that changes continually. More than ever before, the world is facing a threat from climate change. The degree of the impact and its distribution differs considerably between nations based on geographical location and economic condition. The poor and the marginalized nations are facing the worst threats due to this atmospheric $C0_2$ concentration induced global climate change on their major sectors. The prolonged and widespread drought in sub-Saharan Africa since 1983 has been considered to be the result of global climate change(1). The agricultural sector in some countries of temperate zone may benefit from additional warming while many poor economies in the tropics might be more vulnerable to warming due to its effect on the already low water balance and economy's high dependence on agriculture.

The problem seems to be severe in Africa where the main economic activity in most countries is rain fed agriculture. No matter what the nature of this sector is, because water, temperature, and light are the main components of crop growth, the agricultural system is still heavily dependent on the of climate. Hence, climate change may reduce production considerably in sub-Saharan Africa and most nations in the continent may fail to fulfill the quest to feed their people and supply raw materials to the industries. The agricultural sector plays a significant role in the African economy as major source of house hold food supply, raw materials for the agriculture related industries and employment for majority of the population.

Climate change often has devastating effects on agricultural productivity. Increase in temperature and reduction in soil moisture reduces agricultural productivity which is likely to be worse in the tropics due to vulnerability of the agricultural systems to climate change. Increased atmospheric carbon dioxide concentrations may directly affect the crop growth and/or indirectly affect through induced changes in climate by altering levels of temperature, rainfall and sunshine, which in turn affect plant growth(2). In order to know how much to spend on appropriate adaptation and mitigation activities, it is critical to understand the possible effects of long-term climate change on the economy by close investigation of the mechanism through which the economy operates in the face of threat from the change in climate. Most of the empirical work on the impact of climate change on agriculture and the economic modeling and analysis has focused on the northern latitudes and high income countries. Early development on the analysis of the economic impacts of climate change largely ignored developing economies in general (3;4). Little research has focused on developing regions such as those in the tropics and sub-Saharan Africa which may be most vulnerable to adverse changes in global climate.

Problem and Motivation

It is well recognized and documented that climate change has an impact on agriculture. However the extent of the effect and the interplay of the dynamic climatic factors have not been well analyzed in the context of the world poor economies(3). An economy like Ethiopia where agriculture takes the lion share in the economy faces the significant impact from any change in the climate. In such agrarian economy the impact doesn't give way by just affecting the particular sector as there will be a chain of events that will eventually takes place in the economy.

This study will consider the questions of how farming might be affected and by how much; and more importantly how significant is such initial effect on agriculture will be for the whole economy by considering the general equilibrium approach. Temperature and precipitation trends as well as rainfall vary from region to region in the world. What happens to the agricultural economy in a given region, or country will depend on the interplay of the set of dynamic factors specific to each area. Hence, to predict the future course of agriculture in a changing economy the fundamental complexity of natural agricultural systems and the socioeconomic systems matters. Thus, this study focuses on and uses data from Ethiopia, one of the poorest economies in the world, to provide some evidence on the economic impact of climate change from 'the south'.

Purpose of the study

The general objective of the study is to investigate the dynamic interplay of natural environmental factors that affects the economy through its impact on agriculture. In line with this an attempt is made to show the wake up call from the sleepless changing world climatic condition by analyzing its real effect on the poor economies. The main task is to examine the economic impact of atmospheric $C0_2$ concentration induced global climate change that increase temperature and change precipitation pattern.

The common practice in the literature to analyze the impact of climate change in terms of changes in temperature and precipitation is application of the Ricardian approach which is a partial equilibrium model of climate change impacts.[1] In this study by applying the CGE model we can analyze the general equilibrium impact of climate change by capturing the complex economy wide effects. There is a direct initial effect of climate change on the main agricultural sector in the economy which has a strong interaction with the other sectors. Hence by using the CGE model we can analyze the backward and forward linkage between sectors in general and specific impacts on producers, consumers and other institutions.

In order to analyze this economic wide effect a uniform climate scenario and predicted changes in these climate variables are used. To this end the rise in atmospheric temperature and the resulting reduction in water balance in terms of precipitation are incorporated in the CGE model to analyze the impact on the agricultural sector in particular and related industries and the economy in general.

[1] Detail description of the studies can be found in Temesgen (2007)

II. Overview of the Ethiopian Economy

Ethiopian economy is predominantly agrarian. Despite the good resource potential for development, majority of the country's population lives in absolute poverty. Ethiopia is the second largest populous country in sub-Saharan Africa next to Nigeria with population size of 77.1 million(5). The country is one of the poorest nations in the world with per capita income of 146 US dollar (constant at 2000 US $)(5).

The economy remains heavily dependent on agriculture and majority of the population gains its livelihood directly or indirectly from agricultural production. It accounts to the lion share of the GDP and main source of foreign exchange earnings. More than 83 percent of total export earnings in the year 2004/05 were from agricultural exports. From the agricultural products coffee exports accounts for more than 41 percent of foreign exchange earnings, while processed and semi-processed hides and skins are the second important sources of export revenues(6).

The performance and growth in the economy is the direct reflection of the performance of the agricultural sector. The growth in the agricultural sector during the years 2004 and 2005 were 19 and 17 percent respectively which resulted in corresponding proportionate growth in the overall economy(6). The same trend has been observed for decades under which the magnitude and direction of the performance in the economy were determined by the growth path in the agricultural sector.

The manufacturing sector in Ethiopia is at its infancy stage and the country's industrial base is very limited. The composition and share of the industrial sector has been stagnant in which the share of intermediate and capital goods industry is very small. The consumption good industries are the major share while the capital good industries are still limited. In addition, the industrial sector is heavily dependent on semi-processed goods, spare -parts and fuel imported from abroad. The agricultural sector is also the main source of their raw material demand.

The economy has been under a severe macroeconomic imbalance and instability. Fluctuations in national income are due not merely to the decline in demand for Ethiopia's primary agricultural product exports in the world market or to bad economic policy making, but also to the vagaries of weather. Droughts are frequent and severe in many parts of the country and have a devastating impact on the people and the economy. The extreme erosion due to the topographic nature agricultural land and the poor capacity of the soils to retain moisture in most part of the country make the agricultural sector vulnerable to drought. The recurrent drought has claimed many lives in Ethiopia through the tragic famine drama in the 1980s and has been threatening many farm households during the last decades(7-9).

More than 85 percent of the country's population lives in rural areas, where agriculture is the main economic activity. The stagnant agricultural growth and the unpredicted droughts, has resulted in persistent food crises and food insecurity in the country. The challenge is that although the land is fertile the agriculture is rain fed and only one per cent of cropland is irrigated and a period of drought has been leaving the whole country into crisis. Farming is a vital sector in which well above 80% of the country's poor engage and contributing about 48% to the GDP(6). Hence, changes in temperature and precipitation could seriously damage the nation's economy by affecting productivity in the agriculture sector. On top of this, since there is backward and forward linkage with this important sector any wrong happening to it will considerably damage the economy.

III. Review of Related Literatures

CGE Modeling

The computable general-equilibrium (CGE) approach has been widely used for environmental policy modeling research and there are various applications of this analytical tool in the literature. The CGE approach has several advantages over other modeling techniques such as the input–output approach and linear programming for modeling environmental policy and climate change impact analysis. Based on Walrasian general equilibrium theory, the model incorporate market clearance in which supply and demand for goods and factor of production are equated through adjustment in prices.

The model is a system of non-linear equations derived based on the economic theory of optimizing behavior of economic agents. The models also treat prices as endogenous variable and are to be determined by the market(10). Hence, the modeling follows an integration of the producer behavior with the consumer behavior to establish a comprehensive framework for general equilibrium analysis. AS opposed to Input-output analysis, the CGE allows analysis of changes in resourse constraint as well.

Computable general equilibrium modeling enables to simultaneously find equilibrium prices, quantities, and incomes of an economy based on the simple circular flow framework. Furthermore, they are capable of illustrating the respective economic flows in much more detail and also has the main advantage of analyzing the complex inter-linkages between markets, institutions and factor resources and the workings of an economy in an integrated manner and considering the forward and backward effects between all the sectors and economic agents(11;12). Now a days due to the improvement in many aspects of modeling, data availability and further innovations in computer technology, this approach is becoming a widely used analytical tool in many areas in economics(13).

The main criticism of CGE models is the use of highly aggregated variables and parameters and the structural complexity of the various equations used in the analysis. However, the main problem is the manner of communicating the simple underlying ‘’algebraic foundations’’ in the way that is easily understood by the academic communities and policy makers(12).

Climate change impacts studies

There have been many studies on the impact of climate change on Africa. However, most of these studies use the Ricardian approach. The standard Ricardian approach is a cross-sectional method to analyze agricultural production based on a quadratic formulation of climate on farmland net revenue. In their analysis of the impact of climate change on crop land using the Ricardian approach Kurukulasuriya et al. (2006) found that a decrease in precipitation and increase in temperature results in reduction of net revenue per hectare. They have surveyed 9000 farmers in 11 countries in Africa and the implication of their finding was a 10 percent increase in temperature and fall in precipitation results in 13 percent and 4 percent decline in net revenue per hectare respectively. Their analyses of uniform climate scenarios also support the above finding and indicate climate change to be damaging for these economies. While comparing Dry land with irrigated land, due to the precipitation effect on irrigation, dry land agriculture was found to be more sensitive to climate change (14).

Even if such study highlights the impact of climate change on African economies, it has its own limitations by treating African countries together the large variability with respect to how vulnerable different countries are to climate change, as both the underlying climatic condition and the structure of the economies differ between countries. Hence, the impact of climate change can be largely damaging for some countries where temperature and precipitation patterns are worse.

Previous study by Mendelsohn R. et al (2000) considered this limitation and analyzed the regional and country level effects. The results suggested that every region in Africa will experience damage from climate change impacts, but the impact is different between countries as vulnerability to warming is different among nations. As of today there is sufficient evidence to conclude that African agriculture is very vulnerable to climate change due to global warming (15). There have been similar single country studies in Africa and the findings are similar and climate change is damaging for African economies (3;14-19)

Due to the natural interaction between sectors there is no doubt that the Ricardian approach only gives the partial equilibrium effect of climate change. To overcome this various CGE models have been developed to analyze the impact of climate change. Sherony et al (1991) analyzed the impact of crop losses due to climate change on the US economy using the CGE model. The study result showed that crop loss due to climate change will have moderate economic wide effect through the inter-industry interaction and household welfare loss. However, the magnitude of the impact differs among different income group and is generally moderate for the us economy (1) . But the good news is that the impact is minimal for the US economy where the share of the agricultural sector in the overall economy and employment is minimal as well. Similarly, using a CGE model for developed economy, Kokoski and Smith (1987) showed the negative price effects of a CO_2 induced climate change and pointed out that partial equilibrium analysis may give a very misleading results of the economic impacts of change in the global environmental conditions.(20).

One major study using dynamic CGE model in Africa was by Yates and Strzepek (1998) with application to the Egyptian economy. Their finding reveals that the impact of climate change to be insignificant and the ultimate reason could be precipitation effect of irrigation on Egyptian agriculture which can outweigh the negating effect of increase in temperature and change in precipitation pattern due to global warming (21). The Egyptian agriculture is heavily dependent on the Nile basin and irrigation maintains the precipitation pattern and can mitigate the counter productive nature of climate change. All the same Winter P. et al (1996) analyzed the impact of global climate change on developing countries using CGE multi-market models of Africa, Asia, and Latin America to compare the impact of climate change on the macroeconomic performance, resource allocation, and household. Their finding showed that all these countries face potential damage in income and production losses and the effect to be worst for Africa due to lower adaptive capacity(4).

There is no study on the impact of climate change on the Ethiopian economy so far (to my knowledge) as such that explicitly deal with the aggregate economic impact. The only study that specifically examine such impact of global warming was by Temesgen (2007) using the Ricardian approach to measure the impact of climate change on the Ethiopian agricultural sector. Based on data collected from 11 agro-ecological zones in the country the study revealed that climate change has a significant effect on the net revenue per hectare of farmers. In addition, the marginal impact analysis of increasing temperature and change in the precipitation pattern indicated in the study to have a negating effect on net revenue per hectare during the main growing seasons in the country. All the same, the impact analysis of the uniform climate scenarios of increasing temperature by 2.5^{0}C to 5^{0}C and decreasing precipitation by 7% to 14% showed the existence of a damaging impact on the net revenue per hectare.

However, this study only gives the partial picture of the impact of climate change on the Ethiopian economy. The study is too restrictive by only focusing on the agricultural sector and indicates only the partial equilibrium impact on the economy. The agricultural sector is a back bone to the Ethiopian economy and any shock to this sector does not end only affecting this particular sector but passes through the natural inter-linkage with other sectors and will have a multiple effect that reverberate throughout the economy. Hence, the Ricardian approach to analyze the impact of climate change can undermine the magnitude of the real impact. It is from this the present study picks up and tries to fill these gaps.

Role of agriculture and climate change

‘’*Climate change is likely to undermine food production in the developing world, while industrialized countries could gain in production potential*’’.

Jacques Diouf [2]

As it is the case for most Sub-Saharan African nation, majority of the population in Ethiopia lives in rural areas and depends directly or indirectly on agriculture. Its share in the over all economy also confirms that agriculture must be a key component of growth and development efforts. The improvement in this sector also benefits the poor more than the other sectors. However, the poor farmers are facing a new and different challenge.

Agriculture and climate change influence one another. Agricultural practices and deforestation, which is mainly due to expansion in agricultural land, contribute to about one-third of greenhouse gas emissions(22). It is widely argued that expansion in agricultural lands through deforestation reduces biodiversity and contributes to global warming. All the same, agricultural sector is affected by climate change more than any other sector causing crop failure in the tropics and further intensifying the situation of the already food insecure region of the world.

[2] FAO Director-General Jacques Diouf in a speech at the M.S. Swaminathan Foundation Conference in Chennai, India, 7 August 2007

Climate change affects all countries but the poorest people will suffer most because of the heavily dependence on agriculture and geographically they are located in the already warmer tropical region. In Ethiopia, due to global warming minimum temperatures have increased slightly faster than maximum or mean temperatures(23). The 2007 IPCC 4th assessment report also indicates that many countries in Africa already face semi-arid climatic condition that poses challenge on agriculture and this will likely reduce the length of growing season and force most part of marginal agriculture out of production(24). Cline (2007) argued also that global warming affects most the potential of agricultural sector in developing countries because of their geographical location closer to the equator where temperatures are already on or above the thresholds and further warming will reduce crop yields (25).

Climate change is altering the precipitation pattern and level of temperature affecting agriculture capacity to produce enough food and other agricultural products to sustain the livelihoods of rural and urban population threatening the potential of the poor to move out of the trap(22). Sub-Saharan Africa particularly remains the most vulnerable region due to the underlying socio-economic condition that poses a vicious circle. A consequence from any external shock like climate change with the existing complex social and economic disaster will be many folds. This in turn will influence the adaptive capacity of the region and increases the vulnerability of their economy(24). Ethiopia is one of the sub-Sahara African countries that are located closer to the equator and the results from this study can provide some evidence for these underlying theoretical explanations.

IV. Methodology

The purpose of this study is to investigate the economic impact (welfare effects) of climate change. These welfare effects are analyzed through a computable general equilibrium (CGE) model that is programmed in GAMS. The model is based on a Social Accounting Matrix for Ethiopian Economy. The over all activity on the production side is classified as agricultural and non agricultural activities. Each activity uses inputs from the four primary factors (family labor and wage labor, Capital and land) and seven commodities as intermediate inputs to produce eight goods and services in the economy. A twelve-activity with four primary factor inputs and seven intermediate inputs model is developed and implemented through numerical simulations.

The model is informed by the nature of climate condition and agriculture in Ethiopia. The fluctuation in the exogenous climate condition and hence drought is largely responsible for reductions (fluctuations) in agricultural production (6). This leads to negative impacts on the overall economic performance through the inter-linkage with other sector and other economic agents. Agriculture is a significant sector in the economy and any shock to this sector would lead to significant economy-wide effects.

Hence to capture this there is a need to Computable General Equilibrium to model these anticipated impacts. Applying the CGE model helps analyze the interplay of climate factors and its effect on the major sectors and household welfare.

Data source and disaggregation in the SAM

To implement the analysis, the 2005 Ethiopia Social Accounting Matrix (SAM) is used with minor modification to suite the subject at hand(26). The following table shows the disaggregation in the model inline with the adopted SAM for model simulation.

Table 1. Disaggregation of Sectors, consumers (institutions), Goods and Activities

Factor	Family labor Wage labor Capital Land
Consumers (9)	• Institutions Households (Farm household including peasants, wage earners, capitalists), Private firms, Public firms, Government , Rest of the world

- Private investment
- Public investment

Consumer goods and services (8)

- Food crops
- Exportable traditional agricultural products
- Exportable non-traditional agricultural products
- Other agricultural products
- Agro-industrial products
- Other industrial products
- Public services
- Other services

Activities (12) Agricultural activities (3)

- Peasant farming-highland mixed
- Peasant farming -lowland mixed
- Peasant livestock production-pastoralists

Non Agricultural activities (9)

- Cottage handicraft and small scale manufacturing processing
- Public large-medium agro-industry
- Private large-medium agro-industry
- Public large-medium other-industry
- Private large-medium other-industry
- Other public industries
- Other private industries

Analytical model: the CGE model Specification

The model consists of the two main players in the economy: producers and Consumers with the usual optimization problem. The CGE models are typically based on two main behavioral assumptions: the consumer and producer behavior. The consumers maximize utility characterized by a known function subject to a budget constraint. The producers are also assumed to maximize profits by choosing the level of factor inputs subject to production technology.

The formulation of the model follows the standard CGE applications. The domestic production follows a nested production structure due to the difference in the degree of substitutability between factor inputs. Due to the role of intermediate inputs in the production process the activity output is defined as a function of intermediate and primary factors (13). In this study a two stage production structure is adopted. At the top the activity output is a function of 'aggregate value added', and 'aggregate intermediate inputs'. In second level of the nest the aggregated value added are defined by production functions that combine the primary inputs using constant elasticity of substitution function (CES) and the aggregate intermediate inputs are combined by the usual Leontief function

(13) which assumes that the producers use a fixed proportion of the these inputs.

The CGE model is developed with the underlying assumption that the agents make optimal choice under the perfect competitive factor and product market. Hence, assuming that this condition satisfies, the producer will use additional unit of a factor input until the additional factor cost (WF) is equal to the addition to revenue generated by the factor input (MR_F). This condition satisfies the profit maximizing or cost minimizing input choice in equilibrium.

At the top level the output by activity (Q_j) is a CES production function of the following form:

$$Q_j = \phi j \left(\delta_j QA_j^{-\sigma} + (1-\delta)QIT_j^{-\sigma_j}\right)^{-\frac{1}{\sigma_j}} \qquad (e1)$$

Where,

QA_j=aggregate value added of activity j

QIT_j= aggregate intermediate input of activity j

ϕ_j= the scale /efficiency parameter

δ_j =share parameter and σ_j is substitution parameter

Differentiating Q_j with respect to each input we obtain the marginal productivity (MP_F).

$$\frac{\partial Q_j}{\partial QA_j} = \left(-\frac{1}{\rho}\right)\phi j\left[\delta_j QA_j^{-\sigma} + (1-\delta)QIT_j^{-\sigma_j}\right]^{-\frac{1}{\rho}-1}\left[\delta(-\rho)QA_j^{-\rho-1}\right]$$

$$= \phi j\left[\delta_j QA_j^{-\sigma} + (1-\delta)QIT_j^{-\sigma_j}\right]^{-\frac{1}{\rho}-1}\left[\delta QA^{-\rho-1}\right]$$

Multiplying the MP_F by the price (q) of the output we get the MR_F given by:

$$= q\,.\phi j\left[\delta_j QA_j^{-\sigma} + (1-\delta)QIT_j^{-\sigma_j}\right]^{-\frac{1}{\rho}-1}\left[\delta QA_j^{-\rho-1}\right] \qquad (e_2)$$

Applying the optimum condition $W_F = MR_F$ we obtain the equilibrium factor demand equation to be:

$$W_A = q\,.\phi j\left[\delta_j QA_j^{-\sigma} + (1-\delta)QIT_j^{-\sigma_j}\right]^{-\frac{1}{\rho}-1}\left[\delta QA_j^{-\rho-1}\right] \qquad (e_3)$$

$$W_{IT} = q\,.\phi j\left[\delta_j QA_j^{-\sigma} + (1-\delta)QIT_j^{-\sigma_j}\right]^{-\frac{1}{\rho}-1}\left[(1-\delta)QIT_j^{-\rho-1}\right] \qquad (e_4)$$

Taking the first order condition of the profit function defines the optimum input mix.

$$\pi = p.\phi\left(\delta_j QA_j^{-\sigma} + (1-\delta)QIT_j^{-\sigma_j}\right)^{-\frac{1}{\sigma_j}} - qA.QA_j - qIT.QIT_j$$

The optimum input mix is given by:

$$\frac{qA_j}{qIT_j} = \left[\frac{QIT_j}{QA_j} * \frac{\delta_j}{1-\delta_j}\right]^{\rho+1} \qquad (e_5)$$

Where, qIT and qA are prices of intermediate input and value added respectively. The factor demand equation is expressed above as a function of quantities. However, it is possible to use the optimal ratio of input use and insert in the production function to express the factor demand equation , for the profit maximizing output level Q^*, as $Q_A = (W_A, W_{IT}, Q_J{}^*)$ and $Q_{IT} = (W_A, W_{IT}, Q_J{}^*)$.

The optimum input mix satisfies the cost minimization condition in which the economic rate of substitution (the right hand side of e5) is equal to the technical rate of substitution (left hand side of e5), other wise the producer can alter the input use that would result in lower cost way of producing the same output(27)

The production function for the value added at the second nest of the production structure is also given by the CES function of the primary factor inputs as:

$$QV_j = \phi^v{}_j \left(\sum_f \delta^v{}_{f,j} FI_{f,j}{}^{-\sigma^v{}_j} \right)^{-\frac{1}{\sigma^v{}_j}} \qquad (e_6)$$

Where $FI_{f,j}$ = the primary factor, $\phi^v{}_j$ and $\delta^v{}_{f,j}$ are value added scale parameter and share parameter respectively.

The marginal product of factor use is given by:

$$\frac{\partial QV_j}{\partial FI_j} = \left(\sum_f \delta^v{}_{f,j} FI_{f,j}{}^{-\sigma^v{}_j} \right)^{-\frac{1}{\sigma^v{}_j}-1} \left(\delta^v{}_{f,j} FI_{f,j}{}^{-\sigma^v{}_j} \right)^{-\frac{1}{\sigma^v{}_j}-1}$$

Multiplying the MP_F by the output price P we obtain the MR_F. To obtain the Factor demand equation, we require the profit maximizing condition to satisfy the $MR_F = W_F$. Hence, the factor demand equation is given by:

$$W_f = qV * \left(\sum_f \delta^v{}_{f,j} FI_{f,j}{}^{-\sigma^v{}_j} \right)^{-\frac{1}{\sigma^v{}_j}-1} \left(\delta^v{}_{f,j} FI_{f,j}{}^{-\sigma^v{}_j} \right)^{-\frac{1}{\sigma^v{}_j}-1} \quad (e_7)$$

Where, qV is price for value added product.

The intermediate input use is assumed to be Leontief under which the producers use in fixed proportion.. The corresponding Leontief aggregation function for the intermediate inputs is defined as the combination of the intermediate inputs in fixed proportion based on the Leontief coefficient of demand for commodity c by activity j ($Ld_{c,j}$) and is given by the expression

$$QAID_c = \sum Ld_{c,j} * QIT_j$$

Where, $QAID_c$ is the aggregate demand for commodity c as intermediate input.

The optimum condition and the commodity demand equation for the consumers can be obtained by the same fashion. The consumers, on the other hand, maximize utility given by the Constant elasticity of substitution utility function subject to their budget constraint.

$$U_h = \left[\sum (\theta_{jh}) \ (QCD_{jh})^{-\rho}\right]^{-\frac{1}{\rho}}$$

where,

θ_{jh} is Consumer specific expenditure share of consumption spending on good j.

ρ_h is substitution parameter

Each consumer has initial endowments (H)or receipt from factor payment that they rent out and maximize utility subject to the budget constraint

$$\sum P_j QCD_{jh} = qH = I_h$$

Where, I_h is total income and QCD_{jh} is the consumption by consumer h of the goods produced in activity *j.*

Following the standard formulation, expenditure function of the consumer is given by (27)

$$e(\mathbf{P}, U_h) = \left[\sum \theta p^{\eta}\right]^{\frac{1}{\eta}} U \quad \text{where } \eta = \rho / \rho - 1$$

Inverting the above equation we get the indirect utility function which has the form

$$U_I(\mathbf{P}, I) = \left[\sum \theta p^{\eta}\right]^{-\frac{1}{\eta}} I_h$$

Hence, following the *Roys Identity* the household demand function for commodity j (QCDj) is:

$$QCD_{jh} \frac{\partial U_I / \partial p_j}{\partial U_I / \partial I} = \frac{P_j^{\eta_h - 1} \theta_{jh}(I_h)}{\sum\left(\theta_{jh}(p_j)^{\eta}\right)}$$

Where, P_j is market price for commodity j

Based on these equilibrium conditions, the analytical CGE model is developed to analyze the economic impact of climate change on Ethiopian economy.

V. Results and Discussion

Main Results of the study

The prolonged and wide spread drought has been threatening many people in Ethiopia for decades. It is well known that increase in global temperature and decrease in precipitation is considerably hi in countries around the equator. Hence, marginal land is being forced out of agriculture and failure in crop yield has been experienced in Ethiopia due to the recurrent drought in the country. The major crop failure can easily spread through out the economy affecting price and production in both agricultural and other sectors. This in turn influences the purchasing capacity of households that can result in household welfare loss.

The marginal impact of the change in temperature and precipitation are incorporated into the CGE model to analyze the impact on agricultural sector, non agricultural sector and the market interaction in the rest of the economy. To this end, the results from the partial impact analysis done by Temesgen (2006) are referred and used to examine their economy wide effects. The base line estimation was done with the climate change impact parameters equals zero and the climate variables are introduced as external shock to the economy by applying to the relevant sector.

The climate change impact is introduced to the agricultural sector as:

$Q^* = Q^0 + MP_T\Delta T + MP_p\Delta P$

Where, ΔT and ΔP are changes in temperature and precipitation respectively and MP_T and MP_P are the marginal impacts on net revenue of agricultural output of change in these climate variables obtained by the Ricardian approach.

In the base line ΔT and ΔP are set to zero so that $Q^* = Q^0$. To see the impact of change in temperature and precipitation on the agricultural output in the general equilibrium condition and how this impact spread throughout the economy we use some values for the unknown parameters in the model. The values for marginal impact are obtained from Temesgen (2006) and the change in temperature and precipitation are calculated from estimates by Cline (2007). The main growing season in Ethiopia is summer and the values for the marginal impact on net revenue in agriculture were calculated for based on the numerical results for the specified season. The reason to choose this season is that summer is rainy in most part of the country where agriculture is the dominant economic activity and any change in temperature and precipitation during the other seasons of the year will have a minor effect on the agricultural sector in the country as whole. The main results of the model for the interest variables are given in table below.

Table 2: CGE model results for the main interest variables

Production sector		Consumption sector	
variables	% change in output	Consumer class	% change in consumption
Peasant farming	-5.5	Farm households	2
Peasant live stock production-pastoralist	-1	Wage earners	1
Cottage/hand craft and small scale manufacturing	-38	Entrepreneurs	1
Public large-medium agro-industry	-17	Private firms	1
Private large-medium agro-industry	+20	Public firms	2
Other public industries	-36	Rest of the world	1
Other private industries	+20	Private Investment	2
		Public Investment	1
		Government	2

As it can be seen from the table, the agricultural output is decreased by 5.5 percent (relatively lower than what the Ricardian model suggests). The reduction in output under the CGE model is less because it incorporates the possibility of factor substitution as the producers respond to input price rise. The reduction in output has also resulted in an average increase in price of commodity by 10 percent. The rise in commodity price is quite high compared to the reduction in output. The main explanation behind such change in price following the crop failure and the accompanying turmoil in the economy is the food insufficiency condition in the country. The population is growing faster than the growth in production and any reduction in output will put pressure on the price level as there are more people for less bread in the basket. Hence, the decline in crop yields could leave millions without the ability to produce or purchase sufficient food. Agriculture is the most climate-sensitive of all economic sectors and climate change is compromising any effort that is made to bring food sufficiency in the country.

From the industrial sector, public agro industry suffers the most damage of 17 percent reduction in output from climate change as it directly involves in the production of some of the agricultural raw materials which increases the vulnerability of the sector. The Cottage/hand craft and small scale manufacturing sector also suffers the most damage as the demand for their output declines due to the reduction in income of the small households who purchases most of these products. The model also predicted a reduction in the price of land which reflects its lower productivity. This reduction in the value of land also explains the moderate decline in the livestock production which is less susceptible to such losses as the relatively low cost resource-land- goes to this sector through the substitution effect in the CGE framework.

This study did not explicitly treat the impact of climate change on factor input. Climat change can directly affect availablility and productivity of labor and capital for which it is practically difficult to get data for countries like Ethiopia. This, inturn, can undermine how well the CGE model can capture the process of the economy in poor countries. Moreover, the main critic is that the CGE model assumes the possibility of factor substitution, but the reality on the ground in poor economies is the relative rigid nature of substitution between factors of production.

Sensitivity Analysis

The CGE model is utilized under some key assumptions on the values of the parameters and functional forms. Sensitivity analysis is done to evaluate the appropriateness of these choices in parameters by employing some alternative values. The CGE model used incorporates the input-output relationship that allows substitution between the primary factor inputs and between commodities in the consumption sector. The CES function is considered and the degree of flexibility depends on this functional form. Initially elasticity value of 0.8 is used for the top level of the CES production function and the consumption sector and 0.5 elasticity of substitution is used for the value added specification. These values of elasticity of substitution are varied between 0.8 and 0.5 for the sensitivity analysis and the price and output results indicate minimal sensitivity for elasticity changes. Effects on the other sector of the economy are also found to be minor and reporting the result will be almost repeating the above table.

On the other hand, different parameters for the climate change parameters were used following *Niggol et.al (2008)* elasticity results for temperature and precipitation for the different agro ecological zone in

Africa (28). Using these elasticity the responsiveness of net revenue per hectare to percentage change in temperature and precipitation were incorporated in the model for sensitivity analysis as an alternative to the marginal impact parameters taken from Temesgen (2006) in the initial analysis. The over all sensitivity analysis indicates that the results presented in the initial case represent the underlying impact of climate change through the reduction in agricultural output and is not the outcome of the elasticity assumption in the functional forms and the parameter choice for the climate change variables.

VI. CONCLUSIONS

The results of the study indicate the impact of climate change on the Ethiopian economy to be moderate compared to the results from the Ricardian approach in terms of reduction in agricultural output (not aggregate impact which takes into account the consequence on the other sectors as well). However, the people of Ethiopia have been suffering from crop failure due to recurrent drought. This study is based on moderate climate projections of increase in average temperature and decrease in precipitation.

Due to the low adaptation capacity, the high rainfall variability as a result of climate change can worsen the food insecurity situation in the country and a crop failure can create a shock in the economy through the strong inter-linkage between the agricultural sector and the rest of the economy. As indicated in the simulation result of the CGE model the 5.5 percent reduction in the agricultural output has created a 10 percent increase in the price level. This is a direct reflection of the shortage in food crop production and food insufficiency in the economy. Food crop is the major agricultural output in the country. Agriculture is source of income and food for household consumption and any failure in crop production can create a chain of events for the poor farming community. Any loss as a percent of income to the already poor is high no matter how moderate is the over all reduction in output which implies the welfare loss to the low income households.

The poor people who are most dependants on agriculture are the most vulnerable to climate change. Increasing crop failures and livestock deaths are already imposing economic losses in the country. Even if the impact looks moderate in magnitude of reduction in output, the damage for the poor farming community and the food insufficient households is many folds. Furthermore the consequence will get far more severe as global warming continues. More frequent droughts may devastate large parts of sub-Saharan Africa and the entire communities of already poor and vulnerable people in the nation may face the worst in the years to come if actions are not taken. Environment is a 'common asset' and every nation should play a role in combating global climate change. Developing countries should also be part of the solution by reducing deforestation and putting more emphasis on reforestation and more sustainable agricultural practices.

The analysis in this study includes only the impact of climate change in terms of change in temperature and precipitation which can possibly undermine the consequence on agriculture. There are other climate factors that can influence agriculture and other economic activities in the economy. Including them in the analysis of this kind can give a full picture of the consequences of global warming on poor nations that this study did not address.

REFERENCES

(1) Sherony RK, Knowles JK, Boyd R. *The Economic Impact of Crop Losses: A Computable General Equilibrium Approach*. Western Journal of Agricultural Economics 1991;61(1):144-55.

(2) Desanker Paul et.al. : Africa. *Climate Change 2001: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the third Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge UK, 433-467. 2001. Report No.: 3.

(3) Temesgen. Tadesse Deressa(2006) :*Measuring the economic impact of climate change on Ethiopian economy,: A Ricardian Approach,* CEEPA Discussion Paper No. 25, http://www.ceepa.co.za/docs/CDPNo25.pdf 2006.

(4) Winter. P, Muragi R, Sadoulet E, DeJanvry A and Frisvold(1998).*Economic and Welfare Impacts of Climate Change on Developing Countries, Environmental and Resource Economics* **12:** 1-24. 1998.

(5) World Bank. *World Development Indicator 2007*. 2007.

(6) EEA. *Report on Ethiopian Economy*. Addis Ababa, Ethiopia: Ethiopian Economic Association; 2007.

(7) Gebre-Medhin M, Vahlquist B. *Famine in Ethiopia-a brief review*. Am J Clin Nutr 1976 Sep 1;29(9):1016-20.

(8) PANKHURST RICH. *The Great Ethiopian Famine of 1888-1892: A New Assessment ,Part TWO*. J Hist Med Allied Sci 1966 Jul 1;XXI(3):271-94.

(9) PANKHURST RICH. *The Great Ethiopian Famine of 1888-1892: A New Assessment, Part One*. J Hist Med Allied Sci 1966 Apr 1;XXI(2):95-124.

(10) Xie. *Jian and* Sidney Saltzman (2000) *Environmental Policy Analysis: An Environmental Computable General-Equilibrium Approach for Developing Countries ,Journal of Policy Modeling* 22(4):453-489 (2000). 2000.

(11) Serban. S. Scrieciu (2005) *How Useful Are Computable General Equilibrium Models for Sustainability Impact Assessment* ,Impact Assessment Research Centre *Working Paper Series , No.*12 / 2005. 2005.

(12) Ian Sue Wing. *Computable General equilibrium Models and Their Use in Economy-wide policy analysis: Everything you Ever wanted to know* (But

were Afraid to Ask), *MIT Joint Program on the Science and Policy of Global Change* Technical Note No. 6, http://web.mit.edu/globalchange/www/MITJPSPGC_TechNote6.pdf. 2004.

(13) Lofgren H, et.al. *A standard Compputable General Equilibrium (CGE) Model in GAMS*. Microcomputers in policy research 5 2002.

(14) Kurukulasuriya. P.and Robert Mendelsohn (2006**)** *A Ricardian Analysis Of The Impact Of Climate Change On African Cropland*, CEEPA Discussion Paper No. 8 . 2006.

(15) Mendelsohn et al. (2000) *Climate Change Impacts on African Agriculture , CEEPA discussion papaer .* http://www.ceepa.co.za/Climate_Change/pdf/(5-22-01)afrbckgrnd-impact.pdf. 2000.

(16) Mano. R. and Charles Nhemachena (2006) *Assessment of the Economic impacts of climate change on Agriculture in Zimbabwe*: a Ricardian approach, Ceepa discussion paper No. 11. 2006.

(17) Kabubo-Mariara. Jane and Fredrick K Karanja (2006) .*The Economic impact of climate change on Kenyan crop agriculture: a Ricardian approach*. Ceepa discussion papaer No 12. 2006.

(18) Maddison. David.Marita Manley and Pradeep Kurukulasuriya (2006). *The impact of climate change on African agriculture: A Ricardian approach*. Ceepa Discussion paper NO 15. 2006.

(19) Molua. Ernest L and Cornelius M Lambi(2006)**.** *The Economic impact of climate change on agriculture in Cameroon*. Ceepa Discussion Paper NO. 17. 2006.

(20) Kokoski. F. Mary and V. Kerry Smith (1987) .*Ageneral equilibrium analysis of partial equilibrium welfare Measures: The case of climate change*, The american Economic Review. The american Economic Review 1987;77(3).

(21) Yates. D and Strzepek (1998) *Modeling the Nile Basin under climate change*. Journal of Hydroloc Engineering 1998;3(2):98-108.

(22) World Bank. World development indicator 2007, Environment.121-125. 2007.

(23) Canway D, Colin M, Woldeamlak B. *Over one century of rainfall and temperature observations in Addis Ababa*, Ethiopia. International Journal of Climatology 2004 Jan 1;24(1):77-91.

(24) Boko M. I.Niang,A.Nyong,C.Vogel,A.Githeko,M.Medany,B.Osman-Elasha,R.Tabo and P.Yanda,2007:Africa. *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press,Cambridge UK, 433-467. 2007.

(25) Cline. R,William.(2007) *Global Warming and Agriculture: New Country Estimates Show Developing Countries Face Declines in Agricultural Productivity, CGD brief,* , Center for Global Development.. 2007.

(26) World. Bank, "*Ethiopia-A Strategy to Balance and Stimulate Growth", A Country Economic Memorandum*, Report No. 29383-ET, Green Cover, the World Bank January 2005). http://siteresources.worldbank.org/INTETHIOPIA/Projects%20and%20Operations/20328849/Ethiopia%20SAM.xls (Accessed on 16 2008). 2005.

(27) Varian R Hal. *Micro economic Analysis*, 3rd ed. 1992.

(28) Niggol. S. Seo et.al (2008).*A Ricardian Analysis of the Distribution of Climate Change Impacts on Agriculture across Agro-Ecological Zones in Africa*,Policy Research Working Paper no. 4599. 2008.